

**National Aeronautics and Space Administration
Washington, DC**

NASA ADVISORY COUNCIL


July 28-29, 2016

**NASA Glenn Research Center
Ohio Aerospace Institute
Cleveland, OH**

MEETING MINUTES



P. Diane Rausch
Executive Director



Kenneth D. Bowersox
Interim Chair

**NASA ADVISORY COUNCIL
Ohio Aerospace Institute
Cleveland, OH**

**Public Meeting Minutes
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***Meeting Report prepared by
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PUBLIC MEETING

July 28-29, 2016

Thursday, July 28, 2016

Call to Order, Announcements

Ms. Diane Rausch, Executive Director of the NASA Advisory Council (NAC or Council), called the meeting to order and welcomed Council members and attendees to the meeting. She explained that the NAC is a Federal advisory committee established under the Federal Advisory Committee Act (FACA) and as such was subject to relevant Federal regulations and laws. The meeting is open to the public. She noted that meeting minutes would be taken and posted to the NASA website, www.nasa.gov/offices/nac, soon after the meeting. She noted that each NAC member had been appointed by the NASA Administrator based on the member's individual subject matter expertise. All members are Special Government Employees (SGEs), subject to ethics regulations, and must recuse themselves from discussions on any topic in which there could be a potential conflict of interest. Ms. Rausch further noted that all presentations and comments would be part of the public record. Ms. Rausch introduced the NASA Administrator, Mr. Charles Bolden, Jr.

Special Presentation: Transition of NAC Chairs

Mr. Bolden opened his remarks by thanking Dr. Janet Kavandi, Director of NASA Glenn Research Center, for her hospitality, and for enjoyable informal meetings with Glenn employees during the "all hands" session.

with an appreciation of the NAC's difficult task, which is to provide advice and counsel to the NASA Administrator. He characterized this advice as "sometimes robustly received, and sometimes roundly criticized." He recognized that the Chair, acting as emissary of these messages, meets with particular difficulty. He recognized Dr. Steve Squyres, outgoing NAC Chair, as having been exceptional, particularly with advice regarding the planetary system and Mars. His abilities have distinguished him as more than a "normal" Chair, and as "one of the best in NAC history."

Mr. Bolden introduced a "brief change of watch" ceremony, to recognize the transition of the NAC Chairs. The NAC has been in transition in recent months, as Dr. Squyres submitted his resignation in April 2016 with great reluctance due to his pressing commitments. Mr. Bolden described Dr. Squyres as an "amazing, energetic, and dedicated leader," and expressed his sadness at his departure. He recognized that Dr. Squyres was a very busy person, being a Principal Investigator (PI) for the Mars Exploration Rover (MER) Opportunity, a professor at Cornell University, aquanaut, explorer, lecturer, advisor, and of late, a contributor to humanitarian efforts. NASA recognizes the importance of all the NAC members, and knows how highly regarded they are in their respective fields. Mr. Bolden expressed his deep gratitude for the NAC's dynamic group of advisors, crediting their advice in helping NASA to reach new heights, and to reveal marvels of science. Under Dr. Squyres' leadership as NAC Chair, the NAC has met 13 times and submitted a stunning 61 formal recommendations and 62 formal findings to NASA! Many of these recommendations and findings have positively impacted NASA, and have truly made a difference. NASA has responded in writing to every formal recommendation. Mr. Bolden particularly appreciated the NAC's skills in synthesizing this advice, with which NASA has agreed most of the time.

Mr. Bolden formally presented the *NASA Distinguished Public Service Medal* to Dr. Squyres, in recognition of his tenure as NAC Chair from 2011-2016. Mr. Bolden offered thanks on behalf of the "entire NASA family" to Dr. Squyres, adding that he had deeply valued his tremendous support as Chair, and offering his well wishes for the future.

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Dr. Squyres offered brief remarks, noting that it was “impossible to overstate” his respect and admiration for Mr. Bolden, NASA, and the NAC. He stated that he had greatly enjoyed his time in helping to serve Agency in the company of an extraordinary group of people. He summed his commentary by stating his love for NASA, adding that he was stepping away from his role with great sadness. He thanked Mr. Kenneth Bowersox for stepping in as Interim Chair for the NAC, and Mr. Wayne Hale for stepping in as Interim Chair of the Human Exploration and Operations Committee (HEOC).

Mr. Bolden then presented Mr. Bowersox with the “official” NASA gavel, and expressed his appreciation for Mr. Bowersox’s outstanding leadership as Chair of HEOC from 2013 to the present. He concluded his remarks, noting that this is a pivotal time in space exploration, and NASA is getting ready to go through an important transition.

Opening Remarks by NAC Interim Chair

Mr. Bowersox thanked Dr. Squyres and acknowledged his outstanding service as Chair. He said he appreciated his leadership, and having watched him at work, noted that it was impressive to watch how Dr. Squyres had been able to “corral” everyone and come up with useful and actionable recommendations. As Chair, Mr. Bowersox vowed to continue to encourage open and candid communications. He understood that Dr. Squyres found it difficult to depart, but assured him that he cared about NASA just as much as Dr. Squyres did, and shared his concerns. He promised to keep things moving and thanked Mr. Bolden for his trust. Mr. Bowersox called the meeting officially to order.

Welcome to NASA Glenn Research Center

Dr. Janet Kavandi, Director of NASA Glenn Research Center (GRC), welcomed Council members to the Ohio Aerospace Institute. She became GRC Director in March 2015. Comparing her experiences with two centers, GRC and formerly, the NASA Johnson Space Center, she described each center as having its own culture and mission, and she felt that she was acclimating well. GRC is roughly half aeronautics and half space, versus the many scientists and operational staff at JSC. Dr. Kavandi reported enjoying her return to the engineering culture. She noted that Ohio is the birthplace of aviation, and this year GRC is celebrating its 75th anniversary, having started out as an icing research center for aircraft. It is also the birthplace of John Glenn, the first person to orbit the planet, and of Neil Armstrong.

GRC does much work in air and space propulsion, and is still working in air-breathing propulsion. GRC has wind tunnels for testing in the subsonic through supersonic range, and most recently has observed engines operating at high temperatures actually seizing upon experimental introduction of ice; this phenomenon may account for previously unknown flight failures. GRC also flies hyperspectral sensors to investigate the proliferation of hazardous algal blooms (HABs) and detect cyanobacteria in drinking water; studies sound suppression for engines; and conducts research on how volcanic ash impedes engines. The center is working on hybrid electric systems, CubeSat experiments, and is providing exercise harnesses and devices for use on the International Space Station (ISS), and for the Orion vehicle. The combustion and fluid racks on ISS were designed at GRC. The Spacecraft Fire Experiment, Saffire-1, a large flame experiment, as well as experiments on how fluid mechanics change in space, originated at GRC. Communications experiments on ISS are another area of concentration for GRC (e.g., Integrated Radio and Optical Communication; IROC), using quantum packets and laser transmission to enable larger data packets to be transmitted at faster rates. GRC investigations of high-temperature materials and aerogels can benefit the commercial market (sport clothing) as well as protect sensors in extreme conditions, such as those found on Venus. GRC is testing these materials to simulate atmospheric pressures and temperatures over long periods of time. The center is also performing important work in progressing the design of solar arrays and solar-electric propulsion (SEP) systems.

Dr. Kavandi noted that GRC was designated recently as a center of excellence for SEP, a technology that will be demonstrated on the upcoming Asteroid Redirect Mission (ARM). GRC also houses the Plum Brook facility, which houses the largest vacuum chamber in the world, and which is being used for testing Orion, for example. She displayed a BBC-filmed demonstration of a falling bowling ball and feather hitting the floor simultaneously, at vacuum, at Plum Brook, thus clearly demonstrating the law of gravity. GRC is also deeply involved with the Journey to Mars, and historically, with the Hubble Space Telescope (HST). Dr. Kavandi concluded by saying she was looking forward to the future contributions of Glenn Research Center in the years ahead.

Remarks by NASA Administrator

Mr. Bolden addressed the NAC, stating he was pleased to be at GRC in Cleveland, and summarized NASA's "greatest hits over the past year." He stated that he was incredibly proud that NASA is no longer looking at charts and drawings for the Journey to Mars. There is actual hardware for the Space Launch System (SLS) at the Michoud facility, marking progress toward a November 2018 launch of an uncrewed mission. NASA now houses a structure (Bigelow Expandable Activity Module, or BEAM) on ISS, where testing by crew is ongoing. The hope is that the BEAM can soon be used independently. Space X and Orbital ATK both returned to flight this year, carrying cargo to the ISS. Boeing, in its commercial crew efforts, is planning for its first crewed mission to ISS no later than 2018. Planning is in work to develop five X-planes to build and test over the next 10 years, supported by a significant increasing in funding for the Aeronautics division. There is also agreement to allow a ten-year budget swath for this development effort. It remains to be seen if Congress accepts this planning pathway, but it is exciting. NASA recently effected the integration of the Unmanned Aerial System (UAS) into the national air transportation system, expanding international agreements in air traffic management.

The New Horizons mission to Pluto was a resounding success and is now on its way to view a Kuiper Belt object. The Juno mission made it to Jupiter on July 4. Great things are expected upon initiation of its science mission, as well as fantastic imagery from the high-definition cameras. NASA opened its fourth SERVIR hub in Niger, West Africa, an incredible move in partnership with the Agency for International Development (AID), which enables critical access to Earth Science data for almost the whole of western Africa, to support applications such as drought and crop forecasting. Another SERVIR hub was opened in Bangkok, Thailand, and is credited with helping to save thousands of lives in the Bangladeshi floods. NASA looks forward to the October 2018 launch of the James Webb Space Telescope (JWST). JWST's optical telescope assembly is on display at NASA Goddard Space Flight Center (GSFC), where it can be toured by request. The Origins, Spectral Interpretation, Resource Identification, Security, Regolith Explorer (OSIRIS-REx) will be launching to the asteroid Bennu on 8 September, marking the first time the US lands on an asteroid and brings back samples. The mission is a critical step on the Journey to Mars, and for Mars Sample Return (MSR), and will give us a hint at how well we can do this robotically. NASA also continues its many important Earth Science contributions, a small part of which is studying algal blooms around the world. The Agency is continuing to engage academia, industry, and commercial in technology development to enable the Journey to Mars.

Mr. Bolden introduced the NASA Deputy Administrator, Dr. Dava Newman, who also expressed her thanks to Dr. Squyres for his service.

Dr. Dava Newman offered remarks on the Journey to Mars, noting the first phase includes the astronauts' presence at ISS, where they have been continuously for 16 years. ISS is a source of important partnerships, all in preparation for human exploration of Mars. ISS is also a platform where technology development in areas such as miniaturization and ultrasound are expected to find applications on Earth. The second phase of the Journey to Mars will involve NASA's SLS, and the European Service Module now being tested at the Plum Brook facility. The year 2018 is just around the corner, and the 2020s is the decade slated to begin human exploration. NASA needs to continue buy down technology risks in SEP and for in-space propulsion. The Journey will highlight public-private partnerships in developing the space habitats of the future. NASA also has to close the loops on life-support systems; the system is about 65-80% closed on ISS so far, but the figure must be closer to 100% for "boots on Mars." NASA is closer than it has ever been to getting humans to Mars.

Switching gears to space, Dr. Newman invoked the Stratospheric Observatory for Infrared Astronomy (SOFIA), and highlighted its recent observations of novae and supernovae. The Hubble Space Telescope (HST) is now 26 years old and still supporting hundreds of science missions. The Mars 2020 rover will house an instrumental demonstration of *in-situ* resource utilization (ISRU), the MOXIE instrument that will extract oxygen from the carbon dioxide in the Mars atmosphere. There is much to be proud of and celebrate. Investments in technology and innovation are focused on getting to Mars. Exciting Aeronautics work is under way for the development of X-planes; the resulting innovations in supersonics, ultra-efficient engines, and hybrid electrics will lead to commercial payoffs in aviation. It is important to leverage these early investments, and get private folks on board to advancing technology readiness levels (TRLs.) There is no substitute for flight demonstrations and testing to prove these things out. NASA must think about these investments in the continuum from Earth to space.

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NASA efforts in Science, Technology, Engineering and Mathematics (STEM) education include an upcoming “Mission STEM” event at NASA Headquarters in Washington, DC on August 8-9, 2016, to which university partners have been invited to discuss inclusion and diversity, Title IX, and the creation of friendly, inclusive environments to foster STEM education. The intent is to learn from best practices, and to make sure everyone is held accountable. Representation from the National Science Foundation (NSF) and the National Institutes of Health (NIH) will be there as well. It is imperative to battle sexual harassment, and ensure that universities will take action against it. NASA is leading this effort for the U.S. Government.

NAC member Dr. William Ballhaus asked whether progress was being made in understanding the effects of volcanic ash, and how to prevent damage to aircraft engines. Dr. Kavandi replied that testing is being done at NASA Armstrong Flight Research Center, where work is focused on how to make engine components more resistant to ash corrosion. The ideal situation is to avoid shutting down all air transportation, so it is necessary to know where the balance is, as well as how to develop components that withstand the corrosion. Dr. Kavandi felt it was possible for NASA to develop more ice- and ash-resistant componentry. Mr. Bolden commented that as NASA works toward the transition, the centers and Agencies need to identify the unique benefits of NASA research and make them clear to the Nation. No one talked about clear-air icing years ago; GRC identified this phenomenon, which will save lives and hardware in years to come. Many companies are working with NASA on this problem. NAC member Ms. Marion Blakey pointed out GRC’s long history in icing, which is all coming to the fore given some recent incidents. She reported being pleased to be collaborating with Glenn. Mr. Hale noted that as a frequent traveler, he greatly appreciated NASA’s work with the Federal Aviation Administration (FAA), and NASA Ames Research Center. Mr. Bolden added that it has been an incredible year for NASA’s Aeronautics Research Mission Directorate, which has been quietly proceeding with providing concrete tools for air traffic controllers. For instance, ATD2, the third or fourth of a set of tools NASA has handed over to FAA, was specifically designed for relieving ground congestion. It has now been implemented in Charlotte, SC. The tool integrates dispatchers and ground controllers. Another tool, at present being tested by American and United Airlines, will allow pilots to be cleared directly to cruise altitude. This tool will enable billions of dollars in savings on fuel alone. A related tool on the other end of the flight journey will allow an aircraft to descend directly to the runway. A third tool in development is an en-route tool that examines and analyzes suggested routes around weather systems. This tool has been implemented at Dallas Fort Worth airport. Interestingly, the tool announces successful re-routes with a “ka-ching” (i.e., cash register) tone, indicating cost savings to the user.

Ms. Blakey asked Dr. Newman for more information about the STEM summit in August. Dr. Newman briefly described the agenda, which will open with remarks by the Mr. Bolden and keynote addresses from the White House Office of Science and Technology Policy (OSTP). The goal of the summit is to identify challenges with a data-driven discussion. Dr. Newman noted that NASA’s female engineers number only 13% of the engineering work force, and female scientists only 25%. Underrepresented minorities are also represented by very small percentages. This is not where NASA wants to be, and a big question is why NASA is not making progress more quickly. What are the best practices? Some academic environments do have parity; we need to investigate how they do this. Who is doing the best in industry? NASA must specifically address the pipeline, get kids early and young, and change the conversation. What does a space engineer look like? Retention, mentoring, and the entire career arc are also issues to be grappled. Why are people dropping out? Is there support for them? A mentoring program has been set up in association with NASA grants, e.g., to teach universities how to support STEM students. NASA wants to get out the message on Title IX, through reviews, to ensure that the zero tolerance policy is carried out. Universities can share their best practices as well. NASA is also bringing in the Department of Education and Department of Justice to address Title IX and Title VI compliance. Dr. Newman directed interested parties to the website (missionstem.nasa.gov) for more information. This website lists best practices in STEM education, as well.

Ms. Blakey encouraged NASA to be “as granular as possible on data” for STEM education, adding that it would be useful to benchmark practices against what is seemingly effective. Mr. Bolden noted that NASA’s STEM program has its critics; many feel that the subject is “somebody else’s business,” not NASA’s. However, NASA cannot afford to ignore more than 50% of the population, or minorities. Mr. Bolden pointed out that some of NASA’s grant-receiving institutions did not understand how to comply with Title IX, therefore NASA created the Mission STEM website to offer best practices that describe how to comply with the law. NASA has recorded video testimonials from successful universities, and from students who reported feeling comfortable, home and safe in the STEM environment, to help illustrate best practices. Mr. Hale agreed wholeheartedly with Mr. Bolden’s observations, adding that NASA needs people who think differently in order to address different concepts. When diversity is brought into organizations in order to break up the white male cadre, the results speak

volumes. Dr. Newman noted that “unconscious bias” is another area of concern; this bias is not trivial and it is deep-rooted. NASA wants to have the discussion, and to achieve excellence and parity—“we’re all better when we get this right.” Dr. Ballhaus added commentary on how NASA Human Resources had been brought to bear on the question of why named NASA Technology Fellows were mostly male, to figure out how to get more women to stay on the technical track, and to identify mechanisms for mentoring them to be leaders in their field. NAC member Dr. Bradley Peterson commented that diversity should not be considered a goal for its own sake. When people of the same background persist in thinking the same way, they think they are doing fine, which is a confining habit of thought. When diverse individuals are brought into the discussion, it does pay off visibly, very quickly. Dr. Newman felt that there needed to be a step change to help accelerate the progress. She noted that she had done the math, and concluded that if the progress remains linear, “we’ll get there in 150 years.” A “second-order polynomial gets us there in the 2040s”—this is not fast enough. Dr. Kavandi added that it is important to reach students at a young age, and reported being pleasantly surprised at progress she had witnessed in the last decade; she had been seeing many more females in the STEM areas. She noted however that improvements are still not quite as strong for people of color; in this, NASA needs to do better. Parents need to influence their children, too; it is very important to have this kind of support at home. Dr. Ballhaus commented that Dr. Sally Ride often hosted events targeted at middle school students, with parental attendance, and asked if this activity was still going on. Dr. Kavandi reported that “Sally Ride Science” is alive and well for reaching elementary through middle-school students. Dr. Ballhaus commented favorably on a recent “Legoland” event at which Mr. Bolden had made an appearance, adding that it had been “very cool” for his grandchildren.

Mr. Bolden expressed appreciation for the invigorating discussion, expressed his best wishes for a productive NAC meeting, and made his departure.

NASA Human Exploration Update

Mr. Bowersox introduced Mr. William Gerstenmaier, Associate Administrator of the Human Exploration and Operations Mission Directorate (HEOMD). He began his remarks with some memory refreshment on what constitutes the Journey to Mars, stressing that ISS remains first step to Mars, as part of the larger vision. As he stressed to most audiences, the Journey is characterized by the “Earth-Reliant,” “Proving Ground” and “Earth-Independent” phases, all of which fit well with the Global Exploration Roadmap. The critical issue is return times for crew, and not so much the distance. How long will it take to get back to a safe haven, once you go Earth-independent? Currently, this figure numbers in months. NASA must think about the state of ISS life support systems; currently it is insufficient for Earth-independent operation. A deep-space crew will need all the parts for life support, and will need such things as 3D-printing capability. NASA will have to establish new ways of managing risk in this environment. NASA has sent 44 robotic missions to Mars since 1962. It is a reasonable destination, and much is known about it. There are six Mars missions planned for the near future, which will help to better inform us on the human side. The MOXIE experiment on Mars 2020 will hopefully demonstrate ISRU with success. It is important to note however, the number of failures at Mars: 25 of 44. Mars is a complex destination, and NASA will need new risk tolerance strategies to deal with the Journey to Mars going forward.

Mr. Gerstenmaier stated that, “Mars is hard.” It will require the landing of 20 metric tons (MT) on Mars to allow placement of an ascent vehicle on the surface, an accomplishment that is critical to both sample return, and to the return of a human crew. The current capability is 1MT. The “sky crane” will not be adequate for this task due to the vagaries of the Mars atmosphere, thus different approaches, such as supersonic retropropulsion, will be needed. NASA has decided to team with SpaceX’s Red Dragon mission to land a vehicle on Mars. Their target date is 2018, representing a tremendous chance for NASA to get more data on Mars. It is recognized that this is a high-risk mission. NASA will contribute Deep Space Network (DSN) telemetry, and some navigation support from the Jet Propulsion Laboratory, resulting in a very nice merging of NASA and SpaceX expertise. NASA will instrument the SpaceX vehicle to learn about Entry, Descent and Landing (EDL) using retrograde propulsion on Mars. Ms. Blakey asked about the ratio of investment between SpaceX and NASA. Mr. Gerstenmaier felt it was about 10 to 20 fold. HEOMD is not planning to staff up for the mission, as it is thought there is enough “valley time” that there will be no need to add capability. The value of the mission is about \$24M, which Mr. Gerstenmaier did not view as a cost. He did note that NASA will have to watch scheduling, planning time and personnel. HEOMD has been actively sharing its risk posture in this matter.

The Humans to Mars mission is achievable through taking the long view. NASA has dedicated four racks on ISS to life support, and is conducting architecture studies and technology development needed for next steps on this journey,

demonstrating low-TRL activities for oxygen generation, and is trying to achieve significant weight reductions. NASA also sees the private sector as a core feature of the Mars endeavor. There does not need to be 100% alignment in activities between the public and private sectors, but the effort will require teaming, flexibility, agility, and the ability to incorporate the efforts of international and commercial arenas. Diversity is important as well, and is considered critical to the task.

Mr. Gerstenmaier enumerated HEOMD's strategic principles for sustainable exploration:

- Fiscal realism: Implementable in the *near-term with the buying power of current budgets* and in the longer term with budgets commensurate with economic growth;
- Scientific exploration: *Exploration enables science and science enables exploration*; leveraging scientific expertise for human exploration of the solar system.
- Technology pull and push: Application of high Technology Readiness Level (TRL) technologies for near term missions, while focusing sustained investments on *technologies and capabilities* to address the challenges of future missions;
- Gradual build up of capability: *Near-term mission opportunities* with a defined cadence of compelling and integrated human and robotic missions, providing for an incremental buildup of capabilities for more complex missions over time;
- Economic opportunity: Opportunities for *U.S. commercial business* to further enhance their experience and business base;
- Architecture openness and resilience: Resilient architecture featuring multi-use, evolvable space infrastructure, minimizing unique developments, with each mission leaving something behind to support subsequent missions;
- Global collaboration and leadership: Substantial *new international and commercial partnerships*, leveraging current International Space Station partnerships and building new cooperative ventures for exploration; and
- Continuity of human spaceflight: *Uninterrupted expansion of human presence into the solar system* by establishing a regular cadence of crewed missions to cis-lunar space during ISS lifetime.

In addition to adhering to these principles, NASA also continues to work with the international partners on the broader vision. Mr. Bowersox asked if HEOMD would consider the use of transparent communications as a strategic principle, to help inform the supporting community.. Mr. Gerstenmaier commented that the principles should inform internal communications to the team as well. Dr. Ballhaus commented that there is a "lack of urgency" argument: "If you don't get this done this week, then you've slipped a week." He felt there was a need to do better on selling the external decision makers on some kind of schedule for maintaining the core technology investment. The combination of mandatory programs and Congressional mandates squeezes the budget, thus a visible, well-defined schedule is needed to be able to pull off progress in exploration. Mr. Gerstenmaier noted that there is only a finite amount of time left for operations at ISS, which ends in 2024. NASA needs to move out on the low-TRL technologies to be able at Mars by the 2030s. There is absolutely an urgency to pick some technologies to move forward, and to get them on ISS. HEOMD is doing this especially with life support systems. If NASA is to look at landing and systems, it will have to do another development phase in the 2030s that will require major decisions in the 2020s, to prioritize and trade the work. Mr. Gerstenmaier expressed continuing concern about the life support system in terms of reliability and reduced mass. To that end, he noted that HEOMD wants to carry out a long-duration validation run of the Habitation Module in the late 2020s, and is laying out the details to schedule a series of missions to reach this milestone. These details are not ready for publication just yet.

Mr. Bowersox commented that schedule urgency is one way to get focus, but another way is to communicate with numbers. For example, figures of merit could be expressed as: SEP allows reduced mass, or x number of reduced SLS launches. It would be helpful to have quantifiable data. Mr. Gerstenmaier agreed but did not think some of the data could be seen externally; he recommended bringing more technical experts onto the HEOC. Mr. Hale remarked that he had been scheduling more data briefings for future HEOC meetings. Mr. Gerstenmaier offered to give briefings on new designs in process, such as for new lightweight exercise equipment. Dr. Ballhaus suggested that HEOMD try to relate technology investments to measures of effectiveness that people care about. Mr. Gerstenmaier replied that he did possess data of that sort, and would

bring in more specifics at future meetings. He noted that there were some trade space issues such as a potential need for nuclear power on Mars, if it is shown that it is not possible to generate oxygen via ISRU. In 2013, HEOMD tasked system maturation teams to make these trades; these teams can brief on the system trades, if the NAC desires. Mr. Gerstenmaier emphasized that the teams are trying to build a system that does not preclude a new technology coming in later, so that NASA will not have to redesign the spacecraft. The systems would ideally use the same bus, and the same power requirements. This requires rethinking systems engineering and technology development in the extreme; it is really driving the effort.

Mr. Gerstenmaier addressed U.S. human space flight development in general, noting that the flight hardware is scattered around, in projects including the European Orion Service Module at GRC. The hydrogen tank (100 feet long, 144,000 pounds) is currently at New Orleans, and the Orion capsule is in a cleanroom in Florida. NASA is ready to receive final flight service module for EM-1 (which is a year away from flight). HEOMD recently held an ISS research and development (R&D) conference in San Diego, where Mr. Gerstenmaier reported having seen increased interest in microgravity research from a diverse community. The conference had over 700 participants, some of whom were new users, such as pharmaceutical companies, and other novel manufacturing areas. NASA needs to generate revenue from microgravity research, and HEOMD is working hard to disseminate ISS data so others can run with it and innovate. He noted the importance of the Twins Study involving astronauts Scott and Mark Kelly, and the “Omics” (genomics, proteomics, etc.) video series now available on the NASA website. The video series features Omics experts and is very informative, providing explanations in simple lay terms and relating important applications of the research. One intent of Omics research is to be able to predict what diseases one is susceptible to based on one’s genome, paving the way to perhaps using lifestyle or pharmaceutical interventions to prevent disease. The research can also be used to tailor individual drug dosing based on individual gene variation. The videos also describe the nature of genomic changes that occur in microgravity.

With regard to advancing economic development in low Earth orbit (LEO), NASA has been getting interest in the community for attaching modules at ISS. A request for information (RFI) has been released on this subject; the intent is to let proposers operate as a commercial entity at ISS. NASA has extended the response date to 12 August. The RFI was augmented with a NASA blog post that clarifies the RFI in lay terms. The hope is to get an idea of what the commercial demand is for microgravity conditions.

Mr. Gerstenmaier turned to recent activities in the Commercial Crew Program (CCP), which has made good progress over the last quarter, particularly with Boeing and SpaceX advancing their design concepts. This progress is extremely healthy for HEO, as it helps to streamline processes and requirements. Mr. Bowersox noted that CCP was especially useful for informing future programs and projects. With particular regard to the RL-10, NASA wants to have a common acquisition process for that engine. CCP is forcing real integration of this process. Mr. Gerstenmaier displayed milestone charts for Boeing and SpaceX, demonstrating the good hard progress being made. Ms. Blakey asked what the most difficult gate was considered to be. Mr. Gerstenmaier felt that these would be a series of parachute tests, a Boeing wind tunnel test on the skirt around the capsule, and some weight reduction tests. NASA cannot really celebrate or relax until those tests are done. Dr. Patricia Sanders noted and appreciated the many complicating factors for getting certification to fly with crew, as there are so many pieces to it. Mr. Hale felt that from a Program Manager (PM) standpoint, the tall pole would be the design certification review.

ARM has completed Key Decision Point-B (KDP-B) and is in the process of getting the decision memo signed. Solicitations are coming out for science and cooperative activities related to the mission. The Small Bodies Analysis Group of the Planetary Science Subcommittee (SBAG) has been briefed on the mission a number of times. ARM will be a great demonstration for autonomous operations in deep space, and it has real ties to Journey to Mars activities. Work in habitation systems, environmental control and life support, radiation detection and mitigation, and advancing logistics, are all closely tied with STMD.

HEOMD has undergone audits with both the Government Accountability Office (GAO) and the Inspector General (IG). The two most recent GAO audits concerned Orion and SLS. Most issues identified by GAO are ones that had already been identified by NASA and were being worked. Mr. Gerstenmaier stressed the need to “meter the work” in an appropriate manner, and to read more than the executive summary; there are many cross-referenced issues shared with the NASA Aerospace Safety Advisory Panel (ASAP), for example. While NASA needs these external reviews, the Agency sometimes has to push back on them. Mr. Gerstenmaier considered bringing some of the reportage to the HEOC for consideration. Mr.

Bowersox felt that an independent communication chain is a healthy thing. He asked Mr. Gerstenmaier if there had been any surprises in the audits. Mr. Gerstenmaier said that HEOMD largely either knew the issues were coming, or that they were something already in work. He cautioned that some of these reports come from HEOMD's own Standing Review Boards (SRBs), thus they tend to be very critical, as they are intended to be. Such language, if it goes to the media, may be unhealthy as it might prevent SRBs from being so candid. He agreed that the review system needed to be transparent, and that HEOMD would err on the side of full disclosure so that risks can be openly discussed. Mr. Bowersox asked if there were any items that had been closed out. Referring to reports on the risk management process, Mr. Gerstenmaier described those risks as being very old, and having been mitigated.

The QM-2 engine is undergoing final test firings, and moving toward the flight of EM-1. The European Orion Service Module is delayed; however external tanks are complete and are ready to ship to Marshall Space Flight Center (MSFC); the flight hydrogen tank will be built in the next few weeks. There are 900 components going into the engines, where integration and manufacturing are the critical aspects. Mr. Gerstenmaier noted that the "first flow for Orion was rough," and provided some lessons learned on being agile on the floor. These complex schedules require re-planning on a day-to-day basis. Software is going well for the first stage of the rocket. There is a lot of juggling back and forth on the schedule, which Mr. Gerstenmaier felt was part of the process, requiring open communication to avoid a long serial schedule. The auditing teams tend to misinterpret these changing schedules, not recognizing that the schedules are accommodating a first-time process. Welding on an SLS test article is complete. Ground systems development and operations represent five levels of new work platforms for SLS. It is out of phase a little bit in analysis and testing, and some are things out of order. Qualification testing is due to be complete by next year. EM-1 is currently scheduled to launch between September to November 2018 to a distant retrograde orbit around the Moon; the first crewed flight is scheduled for August 2021.

Mr. Gerstenmaier concluded by describing NASA's approach to moving human presence into the Solar System as a huge technical challenge, but he noted that NASA does not need to fund and develop everything. This cooperative approach represents a conscious decision on NASA's part to use shared dependence on the critical path. The budget environment remains challenging, and there are big deltas (on the order of \$700M) that can potentially add stress to the system. HEOMD must therefore continue to work to put into place standards for life support systems, internal systems, and other critical components so that others can contribute. He compared the standardization to a kind of USB port flexibility; i.e. developing a component that can power light as well as transmit data. Ms. Blakey asked how HEOMD was planning for an extended Continuing Resolution (CR). Mr. Gerstenmaier noted that HEOMD should be okay for first part of the year, but added that it will be hard to recover if HEOMD has to make a long-lead expenditure. He summarized that HEOMD was generally in good shape, and actively preparing for a full-year CR.

Council Discussion

Mr. Bowersox thanked Mr. Gerstenmaier for his presentation, and assured him that the NAC recognizes his hard work. Mr. Gerstenmaier noted that his efforts depended on the excellent work force behind him, and stated that there was no question that HEOMD would rise to the challenge. Ms. Blakey recommended that the NAC congratulate Mr. Gerstenmaier on the visibly excellent progress that has been made in HEOMD.

Human Exploration and Operations Committee Report

The HEOC Interim Chair, Mr. N. Wayne Hale, presented his report, noting the unfortunate losses of Richard (Dick) Malow and Patti Grace Smith. The HEOC has brought on two new members, Ruth Gardner and Gerald Smith, while Jim Odom has recently resigned. Mr. Hale reviewed the agenda of the latest HEOC meeting, which included the receipt of status reports from HEOMD, ISS, Exploration Systems Development, Research Subcommittee update, ISS research, the status of ARM, and briefings on System Maturation Teams, the Habitation Module and the status of the Commercial Crew Program. Mr. Hale presented a Flight Planning Integration chart showing who is on board, the various manifests, port utilizations, Soyuz landings, etc. – a very complex international coordination chart. Science utilization on ISS is about 44 person-hours per week, above the target. The BEAM (Bigelow module on ISS) has been inflated and will be onboard ISS for two years of evaluation and testing. Science experiments on ISS include those in human research, Earth and space sciences, biology and biotechnology, and some of which are carried out through the Center for the Advancement of Science in Space (CASIS), which is directed by law to task half the crew research time to the ISS National Laboratory. Featured investigations include a biomolecule sequencer [polymerase chain reaction (PCR) in space], and testing of a phase-change heat exchanger. Fungi

irradiated by the Chernobyl accident are being screened for mutations with potential biomedical or agricultural applications. Mr. Hale presented a chart on items on the integrated path to risk reduction for deep space missions, commenting that hopefully by 2024, NASA will have accomplished most of these items. This will depend on the number of samples and individuals onboard. HEOMD is planning to accomplish as much research as possible while ISS is still operational. Habitation systems will continue testing on ISS and beyond.

Mr. Hale discussed the most recent testing on habitation systems, and in particular, fire detection, fire suppression and clean-up. He noted there had been two smoke incidents on Shuttle, and a significant fire on MIR. To attempt to understand and mitigate fire-associated risk in space, NASA conducted the Saffire-1 experiment, which involved igniting a small fire in a container on a used cargo vehicle after its release from the ISS. This was one of the first of tests in fire detection and suppression, and will help to develop emergency crew masks and lightweight fire extinguishers. Saffire-1 was conducted on June 23, 2016; six or seven more tests are in planning. In response to a question, Mr. Hale said that halon is no longer used for fire suppression, as it is deemed too toxic.

HEOC received a detailed report on Orion and SLS, and was informed of significant progress on both fronts. Mr. Hale briefly reviewed the Exploration Systems Division EM-1 integrated mission milestone summary and critical path, which continues progressing toward 2018. The committee is looking forward to the design reviews for commercial crew, and discussed a possible slippage beyond 2018, when Soyuz seats disappear. HEOC remained concerned about a backup plan should the current program slip. Ms. Blakey observed that NASA is prohibited from using Soyuz beyond 2018 as per Congressional language; Soyuz can be used only if the NASA Administrator determines that there is no alternative capability. This puts NASA between a rock and a hard place. Ms. Blakey asked how the Boeing vs. SpaceX design certification processes work, and if there were expectations that one of these companies would slip its schedule. Mr. Hale replied that he would need an updated milestone chart from each company to make a better assessment. Mr. Bowersox noted that the milestones might have similar names while they may be different in actual content.

The HEOC heard a briefing on ARM and was pleased to note that it is making progress. ARM is currently estimated as a \$1.25B project. When it gets to KDP-C, there will be further cost estimation exercises. The HEOC was also pleased to hear that ARM engaged the SBAG. The mission will function as a planetary defense demonstration that will test high-efficiency SEP, and technologies related to grappling and movement of large masses in space.

Mr. Hale presented three HEOC findings, and some observations and concerns:

Mr. Hale presented an HEOC finding on current NASA status. After Council discussion, the revised finding was approved as follows:

- *The NASA Advisory Council supports the current systematic approach to the ultimate goal of human exploration of Mars that is guided by the three domains of NASA's "Journey to Mars" strategy, which builds sequentially from Earth dependent to proving ground to Earth independent.*
- *We commend the leadership and staff of NASA Headquarters and the Centers for the steady progress being made on the ISS, Commercial Crew, Orion, and SLS.*

Mr. Hale then presented a HEOC finding concerning Soyuz transportation. After Council discussion, the revised finding was approved as follows

- *The NASA Advisory Council is concerned about the possibility of a gap in ISS transportation for NASA crew. The current schedules of both Commercial Crew Program (CCP) providers show completion of certification in time to allow for crew rotation to ISS in CY 2018, however there is very little margin. Human spaceflight development programs invariably suffer schedule slips due to their technical complexity; the integration of commercial providers into government service adds further obstacles to CCP.*
- *It is therefore prudent to assume delays in post-certification missions from today's schedule. Since NASA has purchased Soyuz seats only through CY 2018, any delay of CCP operational capability beyond CY 2018 could result in the inability to send NASA astronauts to ISS until one of the CCP providers can complete certification.*

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- *Due to long lead time required to procure Soyuz seats, a decision must be made by the end of CY 2016 to guarantee access to ISS in CY 2019, or NASA may be forced to reduce – or possibly eliminate – its crew complement aboard ISS.*

Mr. Hale then presented a HEOC finding on technology development and the Mars architecture. After Council discussion, the revised finding was approved as follow:

- *The NASA “Journey to Mars” plan has identified milestone decision points for critical technology incorporation. The determination of technology readiness at those decision points will drive the overall space architecture plan for the long-term.*
- *There are several complex low Technology Readiness Level (TRL) technologies which may be of significant benefit to the Journey to Mars if developed in the proper time. Development starting in the near term will be critical if these technologies are to be considered when the actionable decision time arrives. The measures of effectiveness of relevant technologies will be informed by system analysis.*
- *The Associate Administrators of the Human Exploration and Operations Mission Directorate (HEOMD) and the Space Technology Mission Directorate (STMD) will identify the risk reduction lead times required for those technologies to meet the milestone decision point. Appropriate resource loaded development plans can be established based on these timelines.*
- *Failure of advanced technologies to be developed to the point where they can be selected at the critical milestones will mean that older technology with lesser performance may have to be incorporated in the space architecture.*

Mr. Hale presented HEOC observations from HEOMD presentations:

- HEOMD has added detail to plans for human exploration missions in the 2020’s to identify near term technology development requirements.
- ISS test bed for technology development for deep space exploration is critical and good definition has been made on identifying priorities and critical work to be accomplished during ISS operational lifetime.
- Continued progress is being made on Commercial Crew, SLS, and Orion with no major schedule adjustments due to technical or resource issues.
- ARM planning and development is continuing. The Formulation and Assessment Team’s report has been very helpful. Engagement with the Small Body Assessment Group (SBAG) has improved science potential. Planetary defense objectives have been included.

Mr. Hale presented the top concerns of HEOC:

- Bureaucratic processes that NASA imposes on itself do not always add value to balance their load on the organization and are a threat to accomplishment of NASA’s exploration mission.
- The number and intensity of current reviews of the HEO programs are not helpful and use too many precious resources. The IG and GAO should coordinate and prioritize their reviews.
- Low SLS and Orion Launch rate pose future risks for proficiency of the operations team and reduce program resilience in the event of mission failure
- Budget uncertainty and reduced flexibility in funding accounts make it more difficult than ever for program managers to meet technical and schedule objectives.

Science Committee Report

Dr. Bradley Peterson, Chair of the NAC Science Committee (SC), presented a briefing on the SC's most recent meeting, first reviewing the membership, noting the addition of two new members, Dr. Tamara Jernigan and Dr. Walter Secada. He began with listing of science highlights from NASA's Science Mission Directorate (SMD). In Heliophysics, he delivered a brief "physics lesson" to explain the factors influencing convection in the Sun's tangled magnetic field. He presented images from three different spacecraft – Hinode, Solar TERrestrial Relations Observatory (STEREO-A), and the Solar Dynamics Observatory (SDO) – showing features of "current sheets" on the Sun that may be helpful in predicting solar flares, which can cause serious disruptions to the power grid on Earth. In another highlight, Dr. Peterson displayed extreme-ultraviolet images from Hinode, showing, on the Sun's surface, the distribution of high temperatures at solar maximum and of low temperatures at solar minimum. In Earth Sciences, the satellites Soil Moisture Active Passive (SMAP) and Global Precipitation Measurements (GPM) have been imaging and monitoring aspects of climate change, in the moisture content of the ground and salinity of the ocean. Earth observations are providing a better understanding of how the El Niño oscillation can affect the growth of vegetation. Using this new data, it is now possible to compare absolute vegetation growth against the averages of the last 15 years. In Planetary Science, SMD is celebrating the successful entrance of the Juno spacecraft into orbit around Jupiter, where it will study the origin, interior structure, atmosphere composition and dynamics of the gas giant, analyze the characteristics of the polar magnetosphere, and possibly determine whether or not Jupiter has a solid core. The mission will give clues as to whether Jupiter formed as a mini-star that could not get ignited, or whether it was formed by condensation of heavier materials. If the presence of metallic hydrogen is confirmed, it would imply that the planet has an icy, rocky core. Juno will describe a polar orbit to avoid damage from Jupiter's intense radiation, and will reach its first perijove at end of August, after which the high-first imagery will be released. In Astrophysics, significant highlights include Kepler's latest exoplanet count reaching about 5000, as well as the refinement of the Hubble constant through parallax observations of Cepheid variable stars. The latter highlight is a great leap forward in determining the distances of nearby galaxies.

The SMD organization now has an interim Associate Administrator, Mr. Geoff Yoder, who is currently trying to emphasize that NASA science is interconnected in the effort to answer fundamental science questions. As an example, the launch of Magnetospheric Multiscale (MMS), while a Heliophysics mission in name, also serves to further the understanding of features of stellar formation (Astrophysics); space weather (Earth Science); and the history of water on Mars (Planetary). Juno, a planetary mission, will answer questions about strong magnetic fields and aurorae that are pertinent to Heliophysics; cloud circulation formulation and dynamics (Earth Science); and gas giant exoplanet formation (Astrophysics). Currently SMD is operating a very balanced portfolio. Decadal Surveys provide guidance to NASA through community engagement, providing priorities for science missions as well as science investigations that lead to mission formulation. The Astrophysics Decadal Survey endorsed HST. Dr. Peterson noted that Astrophysics missions, once selected, take 15-20 years to reach operation phase. The next Decadal Survey for Earth Science is due in 2017. Upcoming missions for SMD include OSIRIS-REx, an asteroid sample return mission that will also explore the sustained Yarkovsky effect, which causes the size of an asteroid's orbit to increase over time; this mission also has some relevance to planetary defense. JWST is moving toward an October 2018 launch; its mirror is currently housed at GSFC. The sunshield will keep the telescope at -40C to allow effective observations to be made in the infrared. The Wide-Field Infrared Survey Telescope (WFIRST), a major Astrophysics mission, is now in serious formulation phase, having been partially enabled by the donation of a re-purposed National Reconnaissance Office (NRO) telescope.

The SC received several reports from NASA programs and projects. There is now a NASA Planetary Defense Coordination Office (PDCO) that is detecting and tracking near-Earth asteroids as part of a larger Asteroid Threat Assessment Project, which is considering mitigating strategies, such as nuclear, kinetic or tractor interventions, to deflect a hazardous body from impacting Earth. Early identification is the key to mitigating strategies. Some strategies include possibly changing (darkening) an asteroid's albedo to alter the Yarkovsky effect, a much safer option than nuclear or kinetic means. Dr. Ballhaus asked what sort of actions might be taken in the event of an Earth-imperiling discovery, and which organization would respond. Dr. Peterson reasoned that at some point, agencies beyond NASA would get involved. At present, NASA is just determining threat recognition.

Addressing potential future structural changes within the NAC, Dr. Peterson stated he favored making the current science subcommittees FACA committees, enabling them to directly advise their respective divisions. He felt the change would

improve the efficiency of NAC proceedings. Mr. Bowersox agreed, noting the NAC does not really have the “bandwidth” to have advice going up and down the chain. The Science Committee also heard a briefing from the Big Data Task Force (BDTF), and discovered that the staff at GSFC in particular is dealing very well with preparations for big data. The Committee heard a briefing from the Ad Hoc Task Force on STEM Education, as well.

Dr. Peterson presented one SC observation on technology investment in planetary protection:

The Science Committee welcomes NASA’s renewed attention to investments in the modernization of planetary protection technology and processes. The Planetary Protection Subcommittee notes as well that the ESA Planetary Protection community is currently making similar investments including through the COSPAR PPOSS (Planetary Protection of Outer Solar System Bodies). The Subcommittee recognizes a significant opportunity for NASA to closely coordinate these new planetary protection technology and process investments with analogous investments within ESA and sponsored by COSPAR. For example, ESA is already investing in the development of a sample capture and flight containment system for a possible Mars sample return cooperation scenario. The involvement of the planetary science community in this process would allow integrated options to be presented.

Dr. Peterson commented further on the observation, noting that the Science Committee was that Planetary Protection is receiving timely attention within the Agency, as NASA is at a special time of exploring bodies that could harbor potential life, making it imperative for NASA to avoid forward and back contamination. Forward contamination issue will be very hard to deal with once we send humans to other bodies in the Solar System.

Dr. Peterson the presented an SC finding on Astrophysics data modernization. After Council discussion, the revised finding was approved as follows:

The Astrophysics Data System (ADS) is a large bibliographic, web-based system that provides searchable database of the research literature in astronomy, solar physics, solar-terrestrial interactions, planetary science, Earth science and physics. It is funded out of the NASA Science Mission Directorate Astrophysics data archive program that also supports the Science Archive Research Centers. The ADS, freely available to the public, allows a researcher to locate the entire published literature based on queries of author, title, keyword, astronomical target, abstract or full text. Links are provided to references, citations, and on-line data associated with each article. The ADS is widely used and is an invaluable resource to the research community. For instance, it is not uncommon for a space scientist to have daily use the ADS. ADS datasets are up-to-date and the services developed are at the frontier of digital library services. Other scholarly fields often have weaker and more costly bibliographic systems.

Modernization of the ADS database engine, user and visualization interfaces have been proposed but implementation may not be feasible at current funding levels.

The Council approved this finding for transmittal to the SMD Associate Administrator.

Dr. Peterson presented an SC recommendation on coordination and communication between the NAC Planetary Science Subcommittee and NAC Planetary Protection Subcommittee:

The NAC Science Committee recommends that the Planetary Science Subcommittee (PSS) and Planetary Protection Subcommittee (PPS) begin regular communication regarding the technologies and procedures required to ensure the scientific integrity of returned samples. This is particularly important for astrobiologically significant regions for preventing forward and backward planetary contamination. Involvement of the science community, including astromaterials curation, early in the discussion of science return is critical for mission success. Regular updates on the outcomes of such communication should be given to the NAC Science Committee.

The Council determined that a formal SC recommendation was not needed in this specific case, and that the two groups should be encouraged to commence this work without further delay.

Dr. Peterson then presented an SC recommendation on internal NASA assessment of mission authorization applications to the DOT/FAA by non-governmental entities for planetary protection purposes:

The Planetary Protection Subcommittee of the NASA Advisory Council recommends that NASA's internal assessment of authorization for missions by non-governmental entities include an assessment by the NASA Planetary Protection Office to determine if the proposed mission meets NASA planetary protection policy and requirements.

Mr. Bowersox commented that it was not clear who has the regulatory authority for assessing nongovernmental launches in this case. Dr. Peterson responded that NASA is responsible for assessing planetary protection for any launch on U.S. soil, whether commercial or NASA. Mr. Bowersox called for more discussion of this recommendation to better understand the nuances; the recommendation was tabled.

Dr. Peterson presented an SC recommendation for an additional civil servant Full Time Equivalent (FTE) for the Planetary Protection Office. Ms. Blakey felt the recommendation to be a little too detailed. Dr. Peterson felt it was important to clarify the recommendation and get HEO involved as well, and agreed to reduce the level of "micromanaging" detail in the recommendation. After further Council discussion, the recommendation was revised and approved as a finding, as follows:

The Science Committee finds that additional resources are needed in the NASA Office of Planetary Protection to address increased workload. In recent years, there has been an increase in the number of missions involving planetary protection considerations and in the complexity of those missions. With the growing participation of commercial entities in space exploration, the workload will only increase in the future. Of note, the European Space Agency (ESA) planetary protection office has a larger cadre of staff assigned to the office who supply laboratory capabilities and administrative support. Having additional resources in the NASA Office of Planetary Protection is necessary to ensure ongoing and timely compliance with the Outer Space Treaty. If additional resources are not provided, obligations will not be met in a timely manner, resulting in delays and increased costs.

It was agreed that this recommendation would be directed to the SMD Associate Administrator.

Dr. Peterson then presented an SC recommendation on Hitomi (Astro-H2). Mr. Hale remarked on the number of caveats in the Hitomi recommendation, and Mr. Bowersox felt the recommendation strayed close to particular matters. Ms. Blakey said that she very much appreciated the Science Committee's attention to planetary protection, while she felt there were complicating governance and resource issues, and broader concerns with internationals. She thought the NAC should explore the subject further at next meeting, and applauded the Science Committee for bringing forth the details in depth. Clarifying previous remarks on planetary protection and planetary defense, she felt that planetary defense would seem to fall between NASA, DOD and the White House, and that the FAA would be very willing to collaborate with NASA on planetary protection, to use NASA expertise on making decisions on launch licenses. Ms. Blakey suggested NASA approach the FAA on the licensing issue. Dr. Peterson was requested to revise this recommendation accordingly overnight, and re-present to the NAC on the following day. After Council discussion the following day, the revised recommendation was approved as follows

The Science Committee recommends that NASA proceed with the plan to rebuild the Soft X-ray Spectrometer (SXS) instrument, with the appropriate level of emphasis given to astrophysics decadal survey priorities,

Aeronautics Committee Report

Ms. Marion Blakey, Chair of the Aeronautics Committee (AC), reported on its most recent meeting. She remarked on the remarkable confluence of the AC with the Aeronautics Research Mission Directorate (ARMD), with which the committee has worked closely. The AC has a very wide range of expertise, including an authority on photonics and simulation. She noted that simulation technologies have gone far in helping to spare physical use of the F-22 for training and war games. In addition, the AC's Mike Francis has decades of experience with DARPA, and is an expert on autonomy. New member Greg Hyslop has a background with Boeing as a technology officer, as well as in missile defense and directed energy. Member David Vos of GoogleX has expertise in small unmanned aerial vehicles (UAVs) and has come up with "totally breaking the mold" ideas in unmanned air traffic management (UATM). Ms. Blakey noted that there is no one on the Committee with background at NASA, which is a little unusual, and all the more notable for the committee's confluence with NASA thinking. The Committee talked about the upcoming transition in terms of ARMD's work in environmentally responsive aviation, as these discussions do matter at these "pivot points." She felt ARMD should look at the transition as a time of opportunity, as well as a time to appreciate the status quo.

The Committee explored several areas of interest, the first of which were results of a National Research Council-led study on reduction of global aviation carbon emissions, which has commonality with thrusts in ARMD's strategic research and technology vision (transition to low-carbon propulsion and ultra-efficient commercial vehicles). The NRC committee considered a wide range of options, and the study concluded that the government, industry, and academia will be needed to implement its recommended research agenda. The study identified the best approaches with the potential to reduce carbon emissions: aircraft and propulsion integration; improvements in gas turbine engines; the development of turboelectric propulsion systems; and advances in sustainable alternative jet fuels (SAJF). The study further found that aircraft/propulsion integration and gas turbine issues are well established and need to be pursued, however the path forward is less certain for turboelectric propulsion, as it is not ready for practical application, and SAJF is considered too costly at present. The NRC report is available at www.nap.edu/download/23490.

The Aeronautics Committee discussed the vision for civil aviation, in which there will be a dramatically number of increased flights, reduced flight times, with an eventual goal of six hours transit time to get anywhere on globe, reduced carbon and noise footprints. The Committee felt that ARMD's Thrust 4 Roadmap development efforts in both alternative fuel and hybrid electrics are beginning to converge, and that there is good synergy between the two. Alternative jet fuels will require a lot of modeling and demonstration before certification and operation in 2040s and beyond. Hybrid-electric propulsion for 747-sized jets is also expected to be ready for use somewhere in the 2040s. Mr. Bowersox asked if there were more distributed architecture available for these developments. Ms. Blakey replied that this was the case, and that the Committee also had a discussion of small personal aircraft breaking out of the hybrid-electric effort. Mr. Bowersox noted that personal aircraft might be able to use more automotive-type power plants, which is very much in accord with programs as currently laid out. Ms. Blakey reported that Dave Vos considered GoogleX advances in electric power to be very exciting, as well as their advances in UAVs. It might be good for NASA to collaborate more with GoogleX. It will also be important also to look at vehicle designs, new energy architectures, and fuels.

Ms. Blakey presented a finding for the ARMD Associate Administrator on Thrust 4 Roadmaps. After Council discussion, the finding was approved as follows

The Aeronautics Committee endorsed and complimented the NASA Aeronautics Research Mission Directorate on the way that its strategy has been implemented and agreed that there is a clear beacon to guide NASA's aeronautics program. Specifically in the area of reducing carbon emissions, the Committee encourages NASA to widen the trade space and not be afraid to consider new ideas well beyond the constraints of conventional boundaries. The Committee finds that in this area NASA may need to further incentivize and promote cross pollination of ideas across its various research programs.

Ms. Blakey turned to the subject of NASA's Integrated Aviation Systems Program (IASP), and the development of X-planes in the New Aviation Horizons (NAH) initiative. IASP is conducting flight research on promising concepts and technologies at an integrated system level. NASA already has a high congruence of agreement with industry in this area, making it a good place for commercial collaboration with NASA. The NAH goal is to build five large-scale experimental aircraft to test new technologies, systems and advanced aircraft. Expected benefits of this program are revolutionary advancements, support for advanced design and analysis tools, research results that will inform rulemaking, standards and regulations, and enable US industry to meet future aviation challenges, as well as to inspire a new generation of aeronautical innovators. ARMD has developed a suite of flight demonstration development plans; out of the five aircraft, a supersonic low-boom demonstrator is furthest out. Lockheed Martin Aeronautics Company has a preliminary design contract for a low-boom demonstrator, and NASA has issued an RFP to guide the development of an ultra-efficient subsonic transport demonstrator. Mr. Bowersox asked if there were to be any crewed demonstrators. Ms. Blakey described planning that would allow for autonomous vehicles, for the most part, but the approach will be flexible.

Ms. Blakey presented a finding for the ARMD Associate Administrator on the New Aviation Horizons Initiative. After Council discussion, the revised finding was approved as follows:

The Aeronautics Committee believes that the NASA plan for the X-planes program is an important opportunity to highlight the advance technology development that is driving the future. The Committee agrees that this initiative has concrete and real benefits and will capture the minds of the next generation and will bring excitement to the public. The Committee suggests NASA should open up the aperture to include sub-scale demonstrators and avoid

preconceived solutions that have too many constraints. The Committee views the New Aviation Horizons Program as an incredible opportunity to maintain U.S. world leadership in the aerospace and advance the growth potential of the industry. The Committee commended NASA's efforts in bringing industry, academia and other government agencies to the table to develop the program and support its success.

Ms. Blakey briefly reviewed the 2016 Aeronautics Committee work plan, for which November had been slated to carry out items 8 through 10. Ms. Blakey reported on recent publicity surrounding aeronautics, and reported that ultra-efficient subsonic transport demonstrators are creating excitement, and were recently covered by *Aviation Week*. The X-plane program has also received strong endorsement from the Aerospace Industries Association (AIA) and the American Institute of Aeronautics and Astronautics (AIAA). Dr. Ballhaus expressed his strong support for X-planes, as well.

In terms of broad observations for the transition team, Ms. Blakey stressed that the Committee would want to make a strong endorsement for NAH and X-planes. Mr. Bowersox agreed that the finding might warrant NAC-level attention. Dr. Ballhaus asked whether computation fluid dynamics (CFD) could also be brought to the fore, as the Technology, Innovation and Engineering Committee (TI&E) had recommended a resurrection of engineering methods activity, including CFD, which had subsequently eroded. Ms. Blakey felt it would be wise for the AC to meet with TI&E to further discuss this matter. She agreed to take the issue back to the team and look at the previous recommendation. Mr. Bowersox noted that before a NAC-level finding could be issued for NAH, it would be wiser to wait until after the NAC's visit to Armstrong Flight Research Center. For now, he felt the NAC could approve the findings to the Associate Administrator, and then get the rest of the NAC's approval for a final disposition.

Ad Hoc Task Force on STEM Education Report

Dr. Anita Krishnamurthi, Chair of the Ad Hoc Task Force on Stem Education, addressed the NAC, first reviewing the membership of the Task Force, which she noted as having met three times in 2016. At a time roughly concurrent with the Task Force's creation, she noted that NASA also undertook a Business Service Assessment (BSA) process, which includes Education in its assessment portfolio. In a recent meeting, the Task Force heard a briefing from BSA that indicated its purview was the "how" of NASA Education, while the Task Force was concerned with the "what," eliminating any concerns over a potentially duplicative effort. The Task Force concluded that there exists a complementary opportunity for BSA assess how NASA's Education efforts could be structured, and whether there is a shared ownership or vision; opportunity to collaborate; transparency as to decision-making and who is in charge; and sufficient resources. In effect, the question is: Does the Office of Education have the capacity to be successful?

Dr. Krishnamurthi presented a STEM Task Force finding on a narrower focus for NASA's Education programs:

A narrower strategic focus for NASA's education discretionary/non-directed dollars will help to prevent the agency's education efforts from being spread too thin.

She noted that NASA has many goals and audiences for its education programs and a limited education budget to implement these ambitious goals. The task force believes that focusing on a smaller number of goals and audiences and defining what success looks like for these programs will enable NASA to have more impact and support. She added that the Task Force encourages NASA to consider focusing on particular age bands, geographic areas, segments of the population, or content areas in each solicitation area. To make this determination, NASA should collect and utilize additional data to inform solicitations and strategic directions for NASA's education programs.

Dr. Krishnamurthi then presented a STEM Task Force finding on support for NASA Education grantees and educators' professional development:

NASA education grantees and the larger network of NASA educators and researchers will benefit from deeper connections with the broader STEM education community.

She noted that STEM education research is advancing rapidly and offers insights into design of effective programming. Encouraging increased collaborations with national STEM education focused organizations, including researchers in such organizations, will help individuals be more knowledgeable about the broader context of STEM education research and programming. Engagement can be used to provide ongoing professional development of NASA's education personnel.

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Mr. Bowersox felt that the two findings should go to the Associate Administrator for Education. Dr. Krishnamurthi felt that the first finding could benefit from NAC-level attention and be sent to the NASA Administrator.

Dr. Krishnamurthi presented a STEM Task Force recommendation to appoint a standing external STEM Education task force or advisory committee:

NASA should appoint a high-level external task force or committee to provide strategic guidance and content expertise on all of NASA's education program investment priorities. The Task Force recommends that NASA should appoint a standing advisory task force or committee for education.

Dr. Krishnamurthi commented that while the STEM Task Force recognizes that an internal oversight group already exists, it felt that if Education is a core function of NASA, it could benefit from extra attention; therefore, the Task Force wished the recommendation to go forward at the NAC level. Mr. Bowersox noted that with the NAC restructuring under way, the Task Force might be better aligned at a high-enough level to have weight and visibility, i.e. at the NAC level with recommendations to the Administrator. Ms. Blakey felt that STEM education was important for NASA, that it would be valuable to have input from the broader STEM community, and that NASA should be more fully engaged with it. She personally supported the creation of an external advisory group. Mr. Hale observed that Education has little funding and could not be tasked to "do more stuff." He felt the findings to be contradictory, as the first finding is more about focus, and the second is about getting plugged into the large and vibrant STEM education community, to ensure that NASA is aware of the trends and research, leverage. Dr. Peterson commented that NASA ought to know what the rest of the world is doing in order to figure out what unique contribution NASA can make. He reported that during Science Committee proceedings, the membership felt that the strongest impact NASA could have is in teaching teachers, which is almost impossible for a national agency to deal with. Dr. Krishnamurthi urged more evidence-based investigation to see what gaps the agencies need to step into. The Task Force was not trying to determine what the focus should actually be, but just to look at where NASA is most needed, and where it can most effectively. Mr. Bowersox advised Dr. Krishnamurthi to paraphrase the findings, and to hold the recommendation for a while, so that the NAC might deal with these at its next discussion.

Council Discussion

The NAC discussed the various findings and recommendations, beginning with HEOC. Mr. Hale felt that the first HEOC finding could be combined with the Aeronautics Committee's finding on X-planes. Mr. Bowersox suggested sending the first to the Associate Administrator (AA) of STMD, with the next two to be considered for transmission to the Administrator. Ms. Sanders wanted to endorse the course that NASA is on, consistent with prior NAC leadership, and felt all the findings should go to the Administrator, possibly rephrased. The NAC concurred, and agreed to wordsmith the findings before final approval.

Regarding the finding on the need for a backup plan for Soyuz transport to and from ISS, Mr. Bowersox felt would be a good NAC-level finding after some re-wording. Dr. Ballhaus agreed, commenting that the HEOMD AA could use some "help from his friends." Ms. Sanders felt that visibility of the issue would be helpful. Dr. Ballhaus suggested strengthening the finding to a recommendation. Mr. Hale observed that the recommendation would not be strictly actionable by the Administrator, given restrictive Congressional language. Mr. Bowersox felt the NAC should avoid creating excessive pressure to the commercial crewed vehicle schedule. Ms. Sanders noted that the ASAP had discussed the matter, and that rather than feeling pressured, the program was exploring ways to deal with it. Mr. Bowersox recommended that the finding remain a finding, and asked Mr. Hale to revise it for final approval.

The NAC discussed the finding on the overall architecture of Journey to Mars. Dr. Ballhaus felt that the core program on the STMD side has been very squeezed, and lacked the insight into technology development milestones and the investment needed to make them; there is a real need to "put this on paper soon." Mr. Bowersox noted that the NAC had issued a similar recommendation in the past. Mr. Hale and Dr. Ballhaus agreed to formulate a better finding for consideration on the following day.

Regarding the Science Committee on Hitomi/Astro-H2, Mr. Bowersox suggested a simpler recommendation; i.e. that NASA provide support for JAXA in supporting the mission. The NAC concurred that the revised recommendation be directed to the Administrator. Regarding the recommendation on the need for a Civil Servant FTE for the Planetary Protection Officer, Mr. Bowersox suggested turning it into a finding and directing it to the SMD Associate Administrator.

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As to the recommendation on mission licensing for nongovernmental entities and PPO input, Dr. Peterson felt the process must be clarified, as it is currently unclear how the PPO will assess these launches. Who has the authority and responsibility? He added that NASA also needs to make a decision as to where PPO resides. Mr. Bowersox felt it was fair to direct the recommendation to the SMD Associate Administrator. Mr. Bowersox thought it useful to have a NAC briefing from the Office of the General Counsel on planetary protection responsibilities relative to other agencies. The NAC tabled the recommendation and left it as an agenda item for future meetings. Mr. Bowersox asked the Science Committee and the HEOC to get together again.

The recommendation for PPS and PSS to have regular communication was dropped, as it was recognized that the Science Committee Chair has authority to direct its subcommittees.

The finding on ADS was tabled to give APS further opportunity to comment. Mr. Bowersox felt this to be a potential NAC-level finding, and put it on the approval list. The Science Committee “attaboy” on investments in Planetary Protection technology was put on the observation list.

Friday, July 29, 2016

Call to Order, Announcements

Ms. Diane Rausch opened the meeting and introduced Mr. Bowersox. Mr. Bowersox introduced Dr. Ballhaus’s briefing.

Technology, Innovation, and Engineering Committee Report

Dr. Bill Ballhaus, Chair of the Technology, Innovation and Engineering Committee (TI&E) presented, announcing one new member, Dr. Kathleen Howell. The Committee’s meeting on July 26, 2016, included an update on the SpaceX Red Dragon partnership, a briefing from the Chief Technologist, and tours of STMD projects at GRC. The Committee visited the ECryo facility, and viewed projects on electric propulsion, radioisotope power systems, and large solar arrays, and came away very impressed by the quality of the research. Dr. Ballhaus felt that “human capital at NASA research centers is still very strong.” There are seven STMD thrust areas, which are the focus of cross-cutting technology efforts. Investment themes include efficient space power propulsion, which is one of the key risk reduction steps needed for humans on Mars. Nuclear propulsion may enable a 20-25% reduction in transit time for the Journey to Mars. Mr. Bowersox asked for a clarification; Dr. Ballhaus noted that ARM is now the sole flight demonstration for SEP; there would have to be another demonstration before it could be baselined (for crew). Other propulsion fuels under consideration include multiple oxides of nitrogen-25 (MON-25) MMH development, which are similar to the fuels and oxidizers of the Titan IV era; these are volumetrically higher-performing fuels. Green propellants, CubeSats, advanced solar arrays, planetary surface power, and revolutionary propulsion rockets and thrusters (R&T) are critical investments for STMD as well. Key technologies for high-power SEP demonstration include high-power solar arrays, high-power Hall thrusters, advanced PPUs, and integration of these components.

Dr. Ballhaus reviewed some completed high-power SEP risk-reduction projects, including a system that would be used for ARM. Nuclear thermal propulsion is also being considered for reduced transit time. Mr. Bowersox commented that this would pose a problem with contamination. The STMD Associate Administrator, Dr. Steve Jurczyk, remarked that STMD is considering nuclear thermal in some designs, using low-enriched uranium, which could be tested in Nevada. Mr. Bowersox suggested testing the materials in space and launching them sunward. Dr. Jurczyk noted the latter was “not a crazy idea;” it has been discussed.

MON-25 MMH fuels have another advantage, in that it can be used at low temperatures for operation in extreme environments. They also present some advantages in volume, mass and power. Goals for future MON/MMH engines are to get them to 1/5 the mass, ½ the size, and 1/3 the cost of current designs, with some applications for exploration and science. TI&E will be getting more in-depth briefings on MON-25 MMH fuels in the next few meetings. For surface power, STMD is studying a compact, low-cost fission reactor, scalable from 1-10 kW, using U-235 fuel. This project could use more funding, and has some support from DOE and NNSA.

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SpaceX Red Dragon is working through the roles and missions of the participating organizations, and has established support with NASA through six Technical Exchange Documents (TEDs); NASA is expected to achieve great benefits from the data acquired by the mission. Mr. Bowersox noted that one element of Red Dragon here is NASA advice on planetary protection (SMD). Other participants are HEOMD and STMD. NASA support for the mission is \$6M in FY16 and \$32M over the next four years, largely to support the NASA workforce. NASA is most interested in getting data on supersonic retropropulsion. The Space Act agreement is now in place, but a launch date is not yet defined. The first launch window opportunity is May 2018, followed by another opportunity 26 months later.

TI&E had a discussion with the NASA Chief Technologist, Dr. David Miller, on the restructuring of the Office of the Chief Technologist (OCT), and on streamlining the Technology Roadmap process and the subsequent NRC assessment. OCT and STMD are looking at roles and missions. Dr. Ballhaus expected that the result would be a change in the principal advisor to the Administrator, and moving the execution piece to STMD, which has experienced PMs. The Chief Technologist usually comes in from academia, and helps bring new technology ideas into NASA; it would be useful to get advice from someone who is not competing with other directorates for funding. Prizes and challenges are also being moved into STMD.

Dr. Bauhaus presented one recommendation for the STMD Associate Administrator:

Recommend that STMD conduct an independent study of current small satellite technology developments to determine the appropriate focus for NASA's small spacecraft technology investments.

Dr. Jurczyk noted that in response, a four-month study had been commissioned with the Institute for Defense Analyses, and was currently being implemented. The recommendation was dropped.

The TI&E Committee observations were as follows:

- NASA needs cutting-edge technologies to undertake its missions.
- Current missions are based on technologies developed through investments made over several decades.
 - In the timeframe FY 2005-FY 2009, technology budgets (basic research -\$500M; applied research -\$900M) were drastically reduced.
- Current Administrator has established STMD and made an effort to rebuild the crosscutting technology program. OCT/STMD management has done an excellent job of formulating the technology program and executing it, within annual budget constraints.
 - Example accomplishments: SEP, Green Propellant demo, composite cryotank, small spacecraft technologies, EDL including inflatable decelerator and TPS technologies. And more to come: laser comm, in-space robotic manufacture & assembly, ISRU demo, coronagraph.
 - STMD reengaged the academic community in engineering research and technology development and rekindling interest in NASA among students, especially at the graduate level.
 - STMD has effectively used internal and external partnerships to mature and develop technologies, for example, NASA is beginning to incentivize technology demonstrations on competitively selected science missions (e.g. deep space optical communications on Discovery).

Mr. Hale asked about “locksmithing” methane engine development. Dr. Jurczyk replied that NASA was partnering with industry in an effort to not duplicate effort, and may have to adapt the technology to NASA uses; the directorate is still in formulation phase of that activity.

The TI&E Committee concerns were as follows:

The Agency has increased external and internal appreciation for the importance of funding crosscutting technologies in STMD. However:

- Technology budget priorities have been increasingly driven by factors external to STMD:
 - NASA priorities

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- Congressional direction
- Increasing SBIR/STTR mandate
- The consequence of this is canceled projects (EDL, CPST, LDSD, CEUS) and an inability to start high priority new activities that would give NASA technology options required for future missions (*see next chart*).
- If NASA wishes to have a sustainable, crosscutting technology program, it has to find a more effective way of funding STMD working with its stakeholders.
 - e.g. NASA could develop an agency-wide policy for accommodating SBIR/STTR mandates and top line increases.

Dr. Ballhaus commented that it is too easy to use STMD as a “bill-payer,” which impedes its ability to invest at critical points, due to the long lead times of a typical project. Dr. Ballhaus enumerated STMD thrust areas requiring additional investments:

Lightweight Structures and Manufacturing

- Additional investment in materials, large space structures and manufacturing technology
- Required to meet goals of reducing both mass and cost by 50%

Space Power and Propulsion

- Need to advance solar and nuclear power systems technology
- Required for advanced propulsion systems (SEP and NTP) as well as surface power for Mars and deep space missions (e.g. Europa lander)
- Also need continued investment in chemical propulsion/cryogenic fluids management (CFM)

Autonomy and Space Robotics Systems

- Need investments focused on human-robotic collaboration
- Also should leverage external R&T for highly reliable, autonomous robotic/surface systems

Advanced Life Support and Resource Utilization

- Need to develop more comprehensive ISRU technology strategy/portfolio driven by architecture
- STMD focusing on atmospheric ISRU and in-space/surface manufacturing
- STMD will continue to deliver ECLSS component technologies to HEOMD/AES for system demonstration
- Focus on next-generation, higher risk, higher payoff technologies

Maintain Early Stage investment at ~10% of total STMD portfolio

Dr. Jurczyk noted that it was also important to focus on trade space, and as NASA matures technologies, it must measure the performance of these technologies in the architecture. As plans are laid out for the proving grounds in the 2020s, STMD must also ensure that it makes investments now before those decision points are reached, improve performance, reliability and cost, and continue the collaboration between HEO and STMD. One area STMD does not have good visibility into is systems analysis for missions. Mr. Bowersox cited the Evolvable Mars campaign studies as an example for increasing visibility. Dr. Jurczyk agreed that studies such as these provided good data, but STMD will soon need to narrow down the trade space and set some targets for down-selection; HEO is starting to lay this out. Dr. Ballhaus- the committee would like to see more evidence of this development planning activity at NASA, so we can see some of these mission trades in detail. Hale- know the agency once had a rich cadre of mission analysis planning experts. Ballhaus- concerned that NASA has reduced this cadre of expertise over the last 10-15 years. Hale- OCT moving in agency, Miller going back to academia. Ballhaus- in process of selecting a deputy, permanent CT selection being deferred to after the election.

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Council Discussion

The Council continued discussion of findings and recommendations, beginning with the HEOC finding on the Journey to Mars, as it combines the concerns of both the HEOC and the TIEC. Essentially the finding states that the STMD and HEOMD Associate Administrators should identify the risk reduction lead times required for those technologies to meet the milestone decision points for the Journey to Mars. Mr. Bowersox suggested a softening of language, but agreed that the Council has seen more concrete activity during this meeting period and suggested a revision of the finding, to be put on the approval list.

The Council reviewed findings and observations from the Science Committee. The Science Committee finding on ADS modernization will be brought to the Astrophysics Subcommittee (APS) before it comes back before the NAC as a recommendation. A Science Committee recommendation on internal NASA assessment of mission authorizations for nongovernmental entities was tabled. Dr. Peterson reported he had recently learned that the Space Studies Board would be initiating an 18-month study on relevant policy development for planetary protection, which will include the interests of state and non-state actors. He noted however that if a private company decided to launch before the policy is clarified, NASA might have to deal with these launches on an *ad hoc* basis. A Science Committee recommendation on placement of an additional civil servant in the Planetary Protection Office FTE was redrafted as a finding that will go to the AA. Mr. Bowersox added the finding to the final approval list. A Science Committee recommendation on the JAXA Hitomi mission was approved for the SMD AA. Dr. Peterson felt that previously discussed caveats should remain in the recommendation, as NASA still needs to confirm corrective action has been taken. Mr. Bowersox, Dr. Ballhaus and Mr. Hale concurred with this opinion.

Public Input

Mr. Bowersox opened the line for 10 minutes of public commentary. No public input was received.

Council Discussion and Wrap-Up

Mr. Bowersox made closing remarks, and summarized findings and recommendations.

From HEOC, two findings, and one joint HEOC/TI&E recommendation were to be presented. Dr. Ballhaus offered no further TI&E findings and recommendations, and asked that the NAC discuss sending the observations and concerns list to the Administrator. Dr. Peterson and Mr. Hale briefly discussed community-reported anomalies in the DSN. Dr. Peterson noted that there had been some data actual data loss; contributing factors to the DSN issue include decreased budgets and obsolete equipment. Science Committee had issued a previous DSN finding and was now confirming the numbers before issuing another finding. Mr. Hale expressed personal interest in hearing the results of fact-finding. Mr. Bowersox suggested a rewording of the Science Committee observation on the BDTF to better reflect the fact that it is a concern. Mr. Hale noted that HEOC was to receive a report from Institutional, and was looking forward to hearing their findings and recommendations. The Aeronautics Committee submitted two findings and one recommendation. The Task Force on STEM Education submitted two findings that needed to be combined and reconsidered; one recommendation was tabled.

Mr. Bowersox asked that the NAC keep concerns and observations as a matter of record, either internally or with the Administration, an exercise which might be done annually. Mr. Hale offered no comment. Dr. Peterson felt that concerns and observations should go to all the respective AAs, in addition to the Administrator. Mr. Bowersox agreed. Mr. Hale made a final comment, expressing the wish to revive the Early Career Scientist and Engineer presentations for future meetings.

Adjourn

Mr. Bowersox thanked the meeting support staff. Dr. Peterson commended Mr. Bowersox on his inaugural performance as Interim Chair. Ms. Rausch adjourned the meeting at 11:10 am.



NASA ADVISORY COUNCIL

NASA Glenn Research Center

**Ohio Aerospace Institute
President's Room
Cleveland, Ohio**

PUBLIC MEETING

July 28-29, 2016

Thursday, July 28, 2016

9:00 – 9:03 am	Call to Order, Announcements	Ms. Diane Rausch Executive Director NASA Advisory Council NASA Headquarters
9:03 – 9:15 am	Special Presentation: Transition of NAC Chairs	Mr. Charles F. Bolden, Jr. NASA Administrator
9:15 – 9:20 am	Opening Remarks by NAC Interim Chair	Mr. Kenneth Bowersox Interim Chair, NASA Advisory Council
9:20 – 9:40 am	Welcome to NASA Glenn Research Center	Dr. Janet L. Kavandi Director, NASA Glenn Research Center
9:40 – 10:30 am	Remarks by NASA Administrator	Mr. Charles F. Bolden, Jr. NASA Administrator
10:30 – 10:45 am	Break	
10:45 – 11:45 am	NASA Human Exploration Update	Mr. William Gerstenmaier Associate Administrator for Human Exploration and Operations Mission Directorate NASA Headquarters
11:45 am – 12:00 noon	Council Discussion	All
12:00 noon – 1:00 pm	Lunch	

NASA Advisory Council Meeting, July 28-29, 2016

1:00 – 1:45 pm	Human Exploration and Operations Committee Report	Mr. Wayne Hale, Interim Chair
1:45 – 2:45 pm	Science Committee Report	Dr. Bradley Peterson, Chair
2:45 – 3:00 pm	Break	
3:00 – 4:00 pm	Aeronautics Committee Report	Ms. Marion Blakey, Chair
4:00 – 4:30 pm	Ad Hoc Task Force on STEM Education Report	Dr. Anita Krishnamurthi, Chair (<i>via telecon</i>)
4:30 – 5:00 pm	Council Discussion	All
5:00 pm	Adjourn	

Friday, July 29, 2016

9:00 – 9:01 am	Call to Order, Announcements	Ms. Diane Rausch Executive Director NASA Advisory Council NASA Headquarters
9:01 – 9:15 am	Remarks by NAC Interim Chair	Mr. Kenneth Bowersox Interim Chair, NASA Advisory Council
9:15 – 10:15 am	Technology, Innovation and Engineering Committee Report	Dr. William Ballhaus, Chair
10:15 – 10:30 am	Council Discussion	All
10:30 – 10:45 am	Break	
10:45 – 10:55 am	Public Input	
10:55 am – 12:00 noon	Council Discussion and Final Wrap-Up	All
12:00 noon	Adjourn	

NASA ADVISORY COUNCIL

Membership – July 2016

Role	Council Members
Interim Chair – NASA Advisory Council	Mr. Kenneth Bowersox , U.S. Naval Aviator (Ret.), Former NASA Astronaut
Member at Large	Dr. Wanda M. Austin , <i>President and CEO, The Aerospace Corporation</i>
Chair – Technology, Innovation and Engineering Committee	Dr. William F. Ballhaus Jr. , <i>President and Chief Executive Officer (Ret.), The Aerospace Corporation</i>
Chair – Aeronautics Committee	The Honorable Marion C. Blakey , President and CEO, <i>Rolls Royce North America</i>
Interim Chair – Human Exploration and Operations Committee	Mr. N. Wayne Hale , <i>Consultant, Special Aerospace Services of Boulder, Colorado; NASA (Ret.)</i>
Member at Large, Ex-Officio	Gen. Lester L. Lyles , <i>Chair, Aeronautics and Space Engineering Board, National Academy of Engineering; USAF (Ret.)</i>
Member at Large	Mr. Miles O'Brien , Independent Journalist
Chair, Science Committee	Dr. Bradley Peterson , Professor Emeritus, Ohio State University
Chair, Institutional Committee	Ms. Kathryn Schmoll , <i>Vice President, Finance and Administration (Ret.), University Corporation for Atmospheric Research</i>
Member at Large	Dr. David Spergel , Chair, Space Studies Board, National Academy of Sciences, Princeton University

NASA ADVISORY COUNCIL

MEETING ATTENDEES

NASA Advisory Council Members:

Mr. Kenneth Bowersox, *Interim Chair*
Dr. Wanda Austin
Dr. William Ballhaus
Ms. Marion C. Blakey
Mr. N. Wayne Hale
Gen. Lester Lyles
Dr. Bradley Peterson

U.S. Navy (Ret.)
The Aerospace Corporation
The Aerospace Corporation (Ret.)
Rolls Royce North America
Special Aerospace Services, NASA (Ret.)
U.S. Air Force, (Ret.), *Ex Officio*
Ohio State University (Ret.)

Ms. P. Diane Rausch, *Executive Director*

NASA Headquarters

Dr. Patricia Sanders, *Chair, Aerospace Safety Advisory Panel*

ASAP Representative to NAC

NASA Attendees:

Denning, Elaine
Gerstenmaier, William
Green, Mike
Jurczyk, Steve
King, Marla
Monthey, Lori
Murray, Matt
Rodriguez, Irma
Siegel, Bette

NASA Headquarters
NASA Headquarters
NASA Headquarters
NASA Headquarters
NASA Headquarters
NASA Glenn Research Center
NASA Glenn Research Center
NASA Headquarters
NASA Headquarters

Other Attendees:

Floyd, Mary
Wolny, Josh
Zimmermann, Joan

Ingenicomm, Inc.
George Washington University SPI
Ingenicomm, Inc.

Telecon (Dial-In) Attendees:

McCuhen, Alfred
Riley, Andrea
Williams, Angela
Wilson, Ana
Colangelo, Anthony
Harwood, Bill
Bloomfield, ?
Jacobs, Bob
Bryer, Casey
Chris Gilbert
Thomas, Dan
Branscome, Darrell
Reilly, Deann
Patel, Der
Messier, Doug
Emily Lakdawalla
Morrison, Frank
Mikulka, Gene

University of Arizona
NASA
Ingenicomm
Ingenicomm
Main Engine Cutoff
CBS News
Oceaneering Space System
NASA
Planetary Society
VE Consult
NASA
NASA Consultant
The Boeing Company
Inverse.com
Parabolic Arc
The Planetary Society
Aviation Week
Talking Space

Zucker, H.R.
Grant, Helen
Dean, James
Lochner, James
Zimmerman, James
Foust, Jeff
Rummel, John
Ramos, Jose
Conley, Catharine
Boggs, Kathleen
Cowing, Keith
Smith, Marcia
Carreau, Mark
Dittmar, Mary Lou
McKay, Meredith
Moloney, Michael
Mullins, Todd
Kobayashi, Pestu
Proudfoot, Robert
Gatens, Robyn
Scimemi, Sam
Asmar, Sammy
Barber, Sara
Kamm, Shari
Sofge, Albert
Schierholz, Stephanie
Clark, Steven
Kobayashi, Tetsu
Kronmiller, Theodore
Haltigian, Tim
Perroto, Trent
Hipkin, Victoria
Gonthier, Yves

Hr-Ztech
NASA Headquarters
Florida Today
USR
NASA Retired
Space News
SETI
GAO
NASA Planetary Protection Office
NASA
NASAWatch.com
SpacePolicyOnline.com
Aviation Week
Coalition for Deep Space Exploration
NASA Headquarters
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NASA Headquarters
Asahi Newspaper
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NASA Headquarters
Jet Propulsion Laboratory
U.S. House of Representatives
NASA Headquarters
NASA Headquarters
NASA Headquarters
Quiet Now
Asahi Newspaper
Law Office
Canadian Space Agency
NASA Kennedy Space Center
Canadian Space Agency
Canadian Space Agency

**NASA ADVISORY COUNCIL
NASA Headquarters
Washington, DC
July 28-29, 2016**

LIST OF PRESENTATION MATERIAL

- 1) Welcome to NASA Glenn Research Center [Dr. Janet Kavandi]
- 2) NASA Human Exploration Update [Mr. William Gerstenmaier]
- 3) Human Exploration and Operations Committee Report [Mr. Wayne Hale]
- 4) Science Committee Report [Dr. Bradley Peterson]
- 5) Aeronautics Committee Report [Ms. Marion Blakey]
- 6) Ad Hoc Task Force on STEM Education Report [Dr. Anita Krishnamurthi]
- 7) Technology, Engineering and Innovation Committee Report [Dr. William Bauhaus]